it, for if the fatigue of the red fibres is so great that a real red looks blue-green, why does it not betray itself before the shadowing? If the shadow be removed, the red looks as bright as before.

We are forced to assume that exposure to red light causes a strong disposition to the production of a blue-green sensation, not simply an indisposition to the production of a red sensation. At this point Hering commits a curious error in logic. He thinks that the objection set forth above to the possibility of two complementary colors both containing any considerable amount of green is *more* forcible on the supposition that an image and its after-image correspond to positive and negative forms of one process (viz. growth and decay) than that they correspond to different *degrees* of a positive or a negative process merely. He forgets that the difference between two quantities, both positive or both negative, may easily be as great as that between a positive quantity and a negative quantity. His reviewer, Schön, in *Hermann u. Schwalbe's Jahresberichte über die Fortschritte der Anat. u. Physiol.* gravely sets forth this position of Hering's without comment. The objection is a perfectly valid objection to a three-color theory as opposed to a four-color theory, but it has nothing whatever to say to a theory of assimilation plus dissimilation as opposed to a theory which attributes complementary sensations to the breaking down of two different kinds of chemical substance.

On the whole, this paper of Hering's which contains a large number of ingenious experiments, for the most part carefully weighed, does much to strengthen the belief that the black-white sensation is distinct from the color-sensation, and not composed of its combinations, but very little to strengthen the belief that the sensations of black and white (and of the opposite colors) are the psychological aspect of anabolic and metabolic processes respectively.

The principal weakness at present which exhibits itself on Hering's side of the question is that in his late papers he confines himself to answering objections, and does not sufficiently indicate, at each step, in what way his own theory applies to the case in question. He has promised a full discussion of the subject *de novo*, but that discussion seems to be long in coming. C. L. F.

Ueber den Farbensinn bei indirectem Sehen. Dr. CARL HESS. v. Graefe's Archiv für Ophthalmologie, Bd. XXXV, H. 4, 1889.

This very important paper is a thorough re-examination of the color sensibility of the peripheral portions of the retina. The general results are as follows: (1). Three kinds of homogeneous light can be found, and only three, which change in saturation, but not in color tone, as they are moved toward the periphery of the retina, the eye of course being wholly free from the effects of other color sensations previous or simultaneous. These are a yellow (wave length, 576–574 $\mu\mu$), a green (wave length 497–494 $\mu\mu$), and a blue (wave length 472–470 $\mu\mu$.) The same is also true of a fixed compound color mixed from homogeneous red and homogeneous violet or blue, except where the absorption of the *macula lutea* interferes. (The effect of the *macula* must be regarded in almost all these experiments so far as they are made with mixed colors.) These four unchanged colors are the primary colors (*Urfarben*) of Hering, determined in a purely objective manner. (2) Mixed lights agreeing with these in color-tone, and only such, behave as these do. (3). These four colors, homogeneous or mixed, form two complementary pairs *i. e.*, the mixture of the red and the green and of the yellow and the blue gives white. (4) Reds and greens that differ from the primary red and green become more and more yellow or more and more blue as they advance toward the periphery, finally losing all red and green character and appearing a more or less sat-

urated yellow or blue. The points at which this happens as also that at which the primary colors fade out, depends on the saturation, the size of the retinal area affected, the brightness of the color, the brightness and color of the back-ground, and the radius of the retina along which the colors are advanced. (5) The best method for fixing the point at which the color fails to be seen is to make the back-ground exactly as bright as the colored spot becomes when it has lost its color, in which case it fades into the back-ground and becomes wholly indistinguishable. (6) The colorless brightness or "white valence" of two colors may be assumed to be equal when on losing their color they become indistinguishable from the same back-ground; and the "color valence" of primary red and green may be considered equal when, being mixed in equal quantity the y produce white. Fields of primary red and primary green examined u nder exactly parallel conditions, (*i. e.* when they have equal "white valence" and equal "color valence;" when they are of the same area, are observed with the same portion of the eye and against the same back-ground,) become colorless at the same distance from the center of the field. The same is true for primary yellow and blue. (7) From this it follows that the red sensibility and green sensibility decline exactly together as the periphery is approached; likewise the blue and yellow sensibilities, but much less rapidly. (8) No fixed point can be assigned where these colors will invariably disappear, though such a point can be found for any given set of conditions. (9) White light appears white at all points of the retina. All colors matched on the red-green sensitive part of the eye (except the *macula lutea*) match on all other parts, but colors that match on red-green blind areas, while they match for all other red-green blind areas, do not necessarily match for those that are red-green sensitive. It is hardly necessary to say that most of these observations, which in part support and in part supersede previous observations, are very much more easily explicable on the color theory of Hering than on that of Young and Helmholtz.

The experiments of Hess were conducted with great care; when spectral light was used the eye was kept in the dark for from 15 minutes to half an hour before observation; and care was taken to avoid fatiguing the retinal spot worked upon. The device (one of Hering's) for obtaining a definite area of a definite color in a field of exactly the right shade is especially simple and effective. Through a small round hole in a horizontal screen of gray paper the observer looks down upon the horizontal disc of a rotary color mixer. If the hole is clean cut, the portion of the disc seen below appears in indirect vision simply like a colored spot on the surface of the screen. By changing the inclination of the screen with reference to the light its brightness can be considerably varied, and with a set of interchangeable screens any desired degree can easily be secured. With the same apparatus the "white valence" of colors at the point of disappearance can be measured by the width of the black and white sectors required to make a gray with the disc of the color mixter that shall be indistinguishable from the gray of the screen when the eyes are in the same position as that at which the color disappeared. E. C. S.

Ueber die Hypothesen zur Erklärung der peripheren Farbenblindheit. Prof. EWALD HERING. v. Graefe's Archiv für Ophthalmologie, Bd. XXXV, H. 4, 1889.

In this article, which in a sense furnishes a theoretical and polemical part to the article of Hess above, Hering subjects the explanations of peripheral color blindness advanced at various times by Helmholtz and Fick to a vigorous examination. The first view, conjecturally advanced by Helmholtz, was that the sensibility for red in the peripheral zone was less than for green and blue, approximating a red blindness. This